Reel-to-Reel Selective Plating Processes

Dr. Kan-Lin Hsueh[1] & Dr. I-Yuan Wei[2]

1. *Material Research Laboratories, Industrial Technology Research Institute, ChuTung, Taiwan, R.O.C.*

2. Apex Electrical Interconnection Consultants, LLC, Harrisburg, PA, U.S.A.

ABSTRACT

High-speed reel-to-reel selective plating processes have been practiced in the electrical and electronics connector industries for over two decades. Most frequently, the process selectively coats a layer of precious metal deposit on a designated area. This selective coating offers a connector with desired engineering function and reduces the consumption of precious metal. This paper reviews published literatures and patents. Various configurations of plating cells and plating methods will be discussed.

For more information, contact:
Dr. Kan-Lin Hsueh
N000,Material Research Laboratories/Industrial Technology Research Institute
Bldg. 77, 195 Sec. 4, Chung Hsing Rd.
Chutung, HsingChu, Taiwan 310, R.O.C.

 ©AESF

We will first describe the basic principle of selective plating and report many techniques found in the literature. Then the pros and cons of each technique will be discussed. Detailed cell configuration of each technique will not be disclosed for confidential reason. Hope that this presentation will not only show the tremendous cost benefit of the technology to the connector industry but also lead to further advancement of the selective plating techniques.

Plating On Connector Contact

Copper and its alloys are commonly used as the substrate for the metal contacts of electrical connectors. These metal contacts have several layers of metal coating on their surface. As shown on Fig.1, nickel is generally electroplated over the entire surface of metal contact as a protective layer and as a diffusion barrier to the copper substrate. Tin or tin-lead is electroplated on the nickel surface for soldering purpose. It is electroplated either over the entire contact or selectively on one end of the contact. In order to have a reliable contact, one or multiple layers of precious metals, such as gold and palladium, are then selectively electroplated on the designated region. The electroplating of most contacts is done by reel-to-reel plating process. This process takes feedstock produced from stamping and forming process where the metal contacts are cut and shape. No selective plating technique is used in barrel plating or vibration barrel plating of loose piece contact.

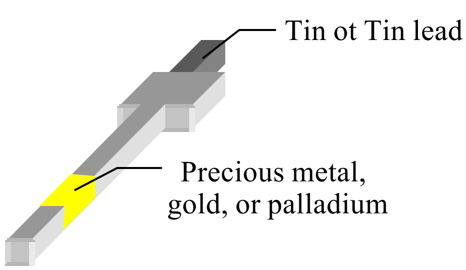

Fig. 1 Typical coatings on metal contact.

Purpose of Selective Plating

Selective plating of tin or tin-lead is to prevent it from coating to the undesired area. This becomes very important where the precious metal coating is close to tin or tin-lead coating on a small contact. Contamination of tin-lead on precious metal can be detrimental. The purpose of selective plating of gold and/or palladium is mainly to reduce the cost of precious metal.

Criteria of Selective Plating

Ideal selective plating shall meet following criteria.

- Confine deposit in designated area
- Deposit thickness distribution and metal composition meet specification
- High plating rate
- Low tooling cost
- Easy and fast alignment of tooling

Many selective plating techniques were developed over past few decades. Each technique meets few but not all the criteria listed above. Each selective plating technique is usually targeted to a special group of contacts.

Category of Contact to be Selective Plated

Although there are thousands of contacts with various sizes and shapes, they can be classified into three categories depending on the area to be selectively plated as following.

Selective plating of contact on

- One-side (Fig. 2 a)
- All-around (Fig. 2 b)
- Internal (Fig. 2 c)

Yellow marks on Fig.2 indicate the plating area.

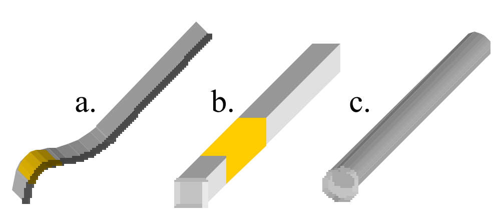

Fig. 2 Category of contact to be selective plated.

©AESF

Selective plating is also applied to plain metal strip. The technique applied is similar to the technique used for individual contact parts.

Principles of Selective Plating

Basic principle of selective plating is to confine and to direct the flow of electrical current to a designate region. The electrical current in the plating bath always seeks the least resistance path between anode and cathode. In traditional plating, additives and conducting salts make the deposit uniform. Conducting salts reduce the resistance of plating bath while additives raise the resistance of deposition reaction on the cathode.

Primary Current Distribution

Figure 3 and 4 schematically depict its effect on the distribution of deposit. A pointed anode and a line of cathode are used as an example. In a 3-D view, this can be viewed as a line anode and a planar cathode. Figure 3 only considers the resistance of the plating bath. Current distribution calculated from the variation of bath resistance is the primary current distribution. The values of resistance marked on this figure are for illustration purpose. Distance between anode and point 'b' on the cathode is the shortest and the resistance between these two points is the lowest.

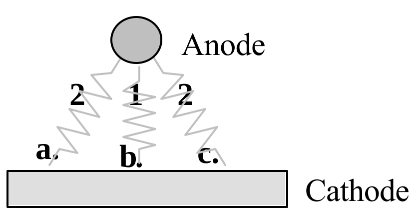

Fig. 3 Equivalent circuit of the primary current distribution of a plating cell

Deposition rate at point 'b' is the highest among points a, b, and c. The distribution of deposition rate is schematically depicted on Fig. 4 as the curve marked 'Primary'.

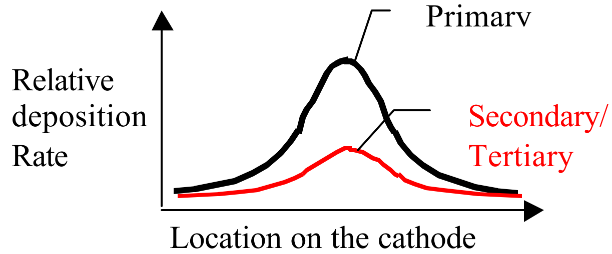

Fig. 4 Relative deposition rate due to primary current distribution and due to the secondary/tertiary current distribution

Secondary/tertiary current distribution

The magnitude of the resistance of deposition reaction on the cathode is much higher than the resistance of the plating bath itself. The resistance of deposition reaction is dependent on the reaction kinetics and concentrations of chemical species, such as metal ions, additives, and hydrogen ions in the bath but not on the distance between anode and cathode. Figure 5 presents the equivalent circuit of this situation. Current distribution calculated by accounting bath resistance and reaction resistance, is the secondary current distribution. Tertiary current distribution considers the resistance due to concentration variation in addition to secondary current distribution. The values of resistance marked in this figure are for illustration purpose. In a well agitate plating cell, the concentration variation across the cathode is relatively small. Additives in the bath raise the resistance of deposition reaction. The resistance due to deposition reaction may be large and relatively constant.

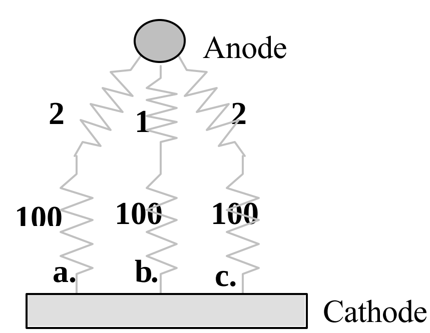

Fig. 5 Equivalent circuit of the secondary/tertiary current distribution of a plating cell

The reaction resistance levels the distribution of current on the cathode. At a given cell voltage, the deposition resistance reduces the deposition rate and evens the current distribution curve as shown on Fig. 4.

Category of Selective Plating Techniques

Current shield or mask is the most common technique employed on selective plating. It confines and redirects the flow of current to the desire region. Based on mask location, selective plating can be classified into following categories.

- Mask on the cathode
- Mask on the anode
- Other novel methods

Wingenfeld presented many selective plating techniques in 1994.

Mask on the cathode

Cathode mask provides direct masking on the cathode and it only exposes the plating area to the solution. Anode condition, such as location, size, and orientation of anode, has little effect on the plating selectivity. A tight fit of the mask, on the cathode is essential. The plating will loose its selectivity when mask is apart from the cathode surface. The mask is practically ineffective when the distance between the mask and cathode is more than 1 cm.

Figure 6 is a computer modeling result of a rectangular plating cell where the cathode has two masks. Short color arrows indicate the direction of current flow and the colors of the arrow represent the magnitude of the current density. Current inside the bath is forced to flow through the opening between the masks. The mask is intentionally set apart from the cathode so that one can see the current flow inside the gap between mask and cathode.

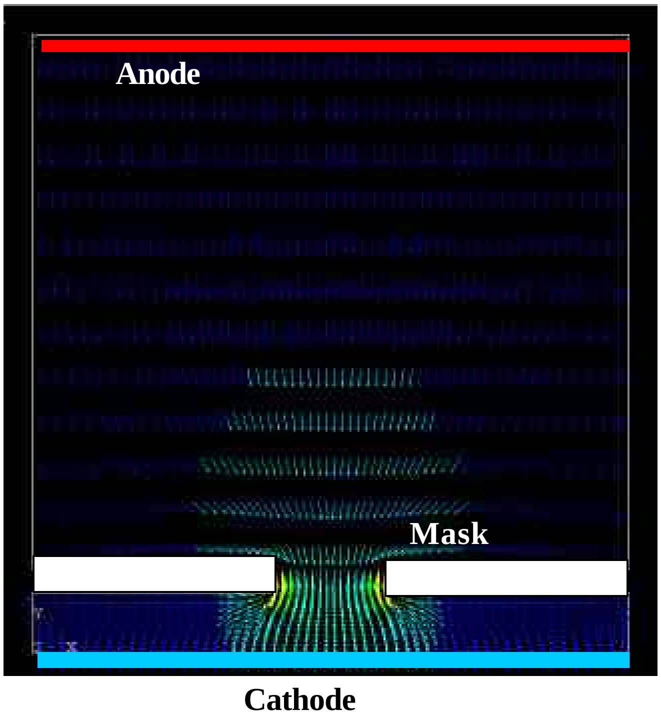

Fig. 6 Calculated primary current distribution inside a rectangular cell.

The cathode is moving at high speed in reel-to-reel plating process. The mask on and off of individual plating part with complex geometry becomes difficult or nearly impossible. An alternate solution of selective plating is to place a mask on the anode that is mounted on the plating cell.

Mask on the anode

Only a small portion of the anode is exposed to the plating solution or in fact, a small anode is used. To make this technique effective, the anode should be close to the cathode or else the plating selectivity will be lost.

Anode mask reduces active area of anode. Consequentially, the current density of the anode is increased. Unfortunately, most plating bath are formulated for low anode current density applications.

©AESF

Mask on the Cathode

There are three type of cathode masking. They are

- Press-on mask
- Coated mask
- Depth control

Press-on mask

The mask is physically pressed against the plating part. It is commonly used on flat stock as shown in Fig. 7. Two wheels rotate the masking belt at the same speed of the plating strip. Index holes on the strip and index pins on the wheel are used to ensure accurate registration of the mask. Plating strip and lower part of the masking belt are immersed in the plating bath. Anode may be placed between the wheels or beside the wheels. This tool can selectively plate out two patterns. Discrete spots of deposit will be plated when the masking belt is moving in sync with the flat strip. A continuous deposit will be plated when the masking belt is stationary.

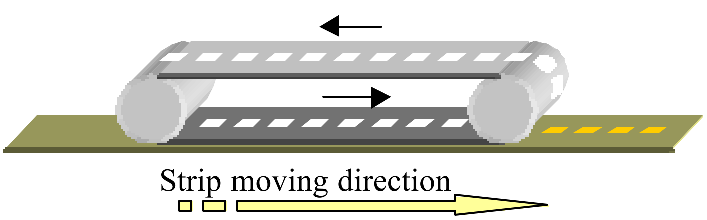

Fig. 7a Typical press-on selective plating with synchronized masking belt.

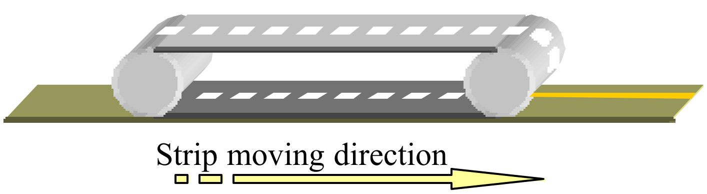

Fig. 7b Typical press-on selective plating with stationary masking belt

Loose fit of the masking belt and strip will cause the decrease of selectivity. Many alternated configurations are used in production.

Coated mask

In the coated mask process, plating strip (Fig. 8a) is traveled through a tank of coating solution and then a dryer where a layer of non-conductive solution is coated over the entire contact (Fig. 8b). The coated contacts then travel through an ablation zone (Fig. 8c) where a beam of high power laser takes off the coating at pre-selected area. This strip is then travels through the plating cell (Fig. 8d) where metal is deposited only on the open area. Finally, the strip is immersed in a solvent (Fig. 8e) where the coating material is dissolved. Wu et al. received a patent on selective plating by laser ablation.

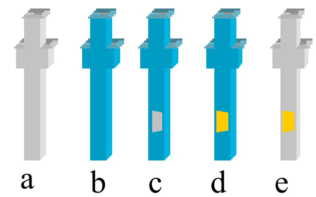

Fig. 8 Plating part at various stages of the coated masking process

This method can selectively plate multiple spots at the same time. The plating area can be rectangular, triangle, or other shapes. However, due to the nature of laser beam, it is limited to selective plating of a relatively flat plating surface.

Depth control

Depth control selective plating is done by partially immersing the plating part into the bath as shown on Fig. 9. It is commonly used to selective plating of one end of the contact. The setup is simple and low cost. Adjusting the bath level controls the area of the plating portion. However, selectivity is only fair. Comp received a patent similar to the one shown on Fig.9.

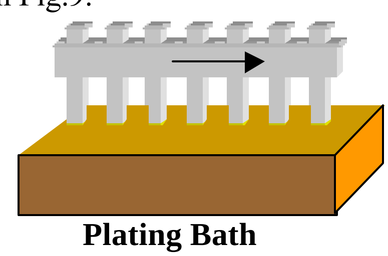

Fig. 9 Depth control selective plating

©AESF

The strip has to move slowly through the bath to avoid disturbing the bath surface. At high moving speed, the movement of pins generates wakes on the bath surface and the plating selectivity is diminished.

Current Shield on the Anode – Proximity Plating

Anode mask can be classified into following three types.

- Brush plating
- Proximity anode for external plating
- Proximity anode for internal plating

Brush plating

Brush plating uses air as the mask. A piece of porous cloth saturated with plating solution is commonly used as a mean of bath confinement. It confines the flow of plating bath and limits the bath in contact with the plating part at the designated area. Fig. 10 depicts two typical tools of brush plating. On the left of Fig.10, is a rotating drum, the anode. A porous cloth saturated with plating solution covers the drum. Spent bath is squeezed away at the bottom of the drum. The bath solution is replenished from the perforated drum. Smaller drum produces smaller plating area. Tool on the right hand side of Fig.10 produces finer pitch of plating than the drum. However, its plating rate may be lower than the drum because of its low replenishing rate of plating bath. Eidschun et al., Wingenfeld et al. and Palnik separately received their patent on brush plating similar to the tool on Fig 10.

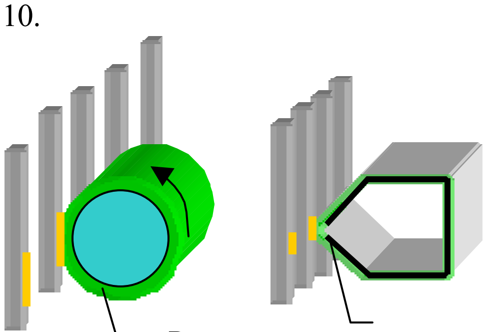

Fig. 10 Two common types of brush plating

A "liquid" brush plating tool eliminates the need of cloth and has better bath replenishing rate than the cloth brush plating. As shown on Fig.11, a liquid fountain is traveled through a narrow slot and it is flowing upward. Bath is in contact with the plating part at the designated area. The flow rate of bath is carefully adjusted so that the shape of the wet portion remains consistent. The anode is placed inside the box. Smith received a patent of this technique in 1989.

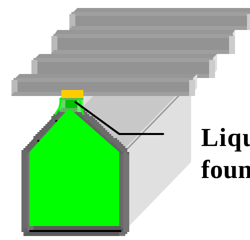

Fig. 11 "Liquid" Brush plating

The flow of solution is kept low so that the plating area will not be flooded and looses its selectivity. Therefore, the replenishing rate of solution is low. This limits its plating rate. Instead of confining the solution flow, using a small anode can also achieve selective plating result.

Small anode – anode proximity plating

The anode in the anode proximity plating is a piece metal sheet or wire as shown in Fig. 12. To achieve good selectivity, anode is placed as close as possible to the plating part. Solution can be vigorously agitated.

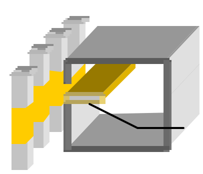

Fig. 12 Proximity anode selective plating

This type of anode experiences high anodic current density. The plating bath may degrade and the anode may need frequent maintenance.

©AESF

Small anode – internal plating

PIRA, Precision Insertion Retractable Anode, is a unique tool for selective plating of the internal of a socket. As shown on Fig 13, the anode is a small piece of metal wire. It inserts into the socket and the plating current flows through it. After plating, the anode is retracted to its original position and waits for next plating part. Smith and Wagner received a patent of this selective plating.

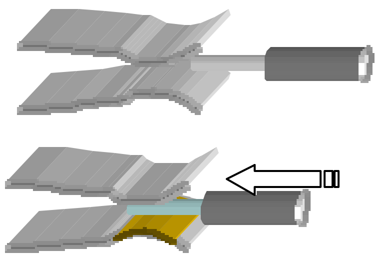

Fig. 13 Internal selective plating

As an anode proximity plating, PIRA anode also has high current density and needs regular maintenance. This cell involves sophisticated machinery to register the anode position and to switch on/off of the current.

Summary

We report several selective plating tools found in the published literature. Mask on cathode is used for plating part with flat surface. For complicated plating parts, brush plating can be used for one-side selective plating. Anode proximity plating is applied for all-around selective plating. PIRA can be used for selective internal plating.

Acknowledgements

The authors would like to dedicate this paper to our beloved former colleague, Mr. Richard M. Wagner, in memory of his innovation and excellent service in the Department of Plating Research, AMP Inc. for more than three decades. He was the leading designer and had spent a decade for perfecting the art of an internal selective plating process named PIRA (Precision Insertion Retractable Anode).

Reference

1. Comp, Richard J., US Patent 4,904,363 (1990)
2. Eidschun, Chsarles D., US Patent 4,361,470 (1982)
3. Georgiadou, M, D. Veyret, and R.L. Sani, J. Electrochem. Soc., 148 (2001) C54
4. Palnik, Karl, US Patent 4,610,772 (1986)
5. Palnik, Karl L., US Patent, 5,116,480 (1992)
6. Smith, Mark L., US Patent, 4,818,349 (1989)
7. Smith, Mark L. and Richard M. Wagner, US Patent 4,690,747 (1987)
8. Wingenfeld, Peter and Dietmar Holdt US Patent 4,952,296 (1990)
9. Wingenfield, P, Metal Finishing, Jan (1994) 13.
10. Wu, Jeff C., Richard T. Williams, John R. Rowlette, Charles P. Brooks, Richard H. Zimmerman, US Patent 4,877,644 (1989)

©AESF